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SELECTED TRANSLATIONS

FROM

SOVIET-BLOC INTERNATIONAL GEOPHYSICAL YEAR LITERATURE

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Arctic and Antarctic

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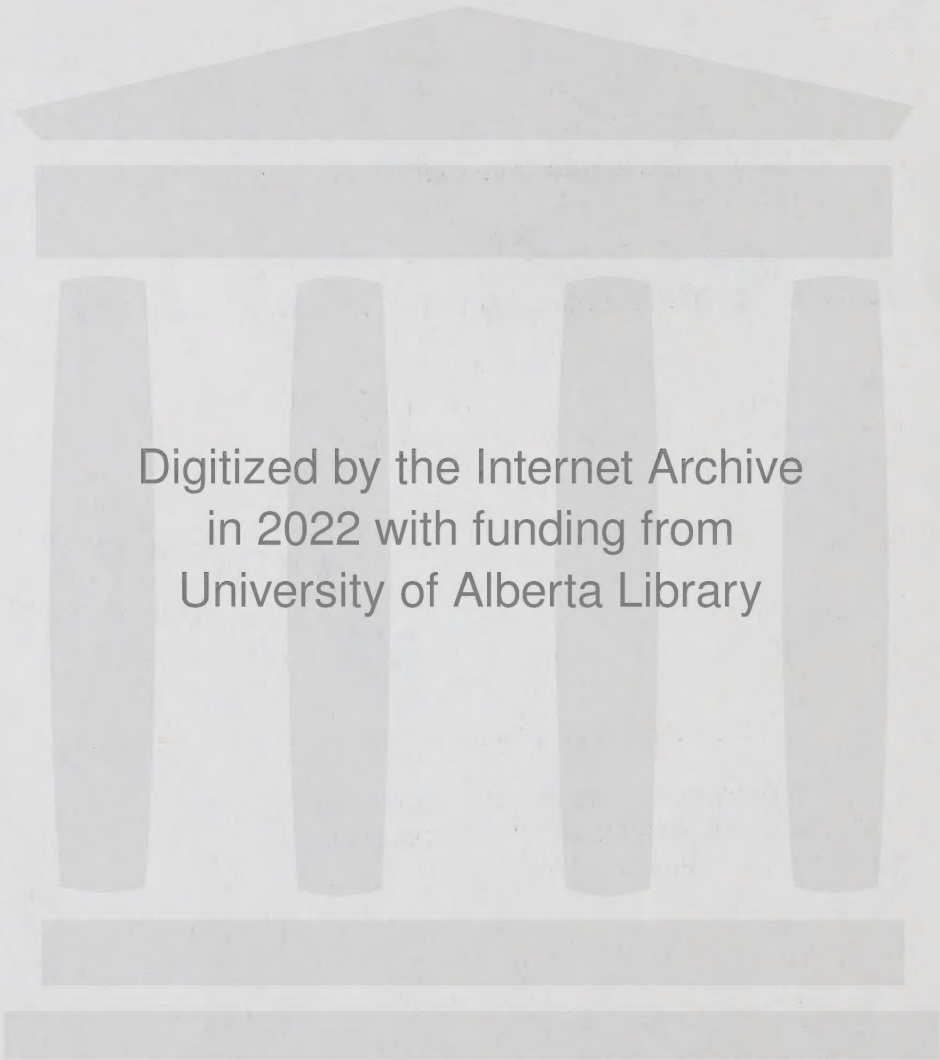
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NEW DATA ON THE GEOMORPHOLOGY OF EASTERN ANTARCTICA

Nauchnyye Doklady Vysshey Shkoly,
Geologo-Geograficheskiye Nauki
/Scientific Reports of the Higher School,
Geological-Geographic Sciences/,
No 3, 1958, Moscow,
Pages 51-54
Russian Per.

P. S. Voronov

During the conduct of terrestrial geological investigations, on the staff of the First Soviet Antarctic Expedition from January 1956 to February 1957, the author was able to observe a series of interesting peculiarities of the basic relief of the coast of Eastern Antarctica between 75 and 110° east longitude, that is from Ingrid Christensen Coast to Budd Coast. Among these peculiarities are: the character of glacial striation of rocks; marine terraces; and also neotectonic disjunctive complications of the continental shelf. Let us examine each of them.

A. Glacial striation. Glacial striations, scars and furrows are encountered quite often along the whole coast of Eastern Antarctica investigated by the expedition, on the surfaces of rocky elevations formed by pre-Cambrian metamorphic and igneous rocks. Among these traces of grooving, glacial striation and scars are widely distributed. Glacial furrows were noted only in individual cases; their length, moreover, did not exceed a few meters and their width 10-15 cm, with a depth of 5-10 cm.

Striation and scars are usually located on the surface of leveled areas of varying size formed on the rocks by the ancient blanket glaciation of Antarctica (see figure). Systematic observations of striation and scars were carried out only on the surfaces of these sloping or horizontal areas, since only on them can the maximum coincidence of direction of striation with the former general direction of movement of the ancient glacial coverings of Antarctica be expected.

Study of the character of glacial striation on the coastal nunataks, and islands near the coast, in the region of Mirnyy made it possible to establish that glacial striation and scars are not oriented chaotically here, but are clearly divided into three systems of different ages, with mean courses on the azimuths: 350° (the most ancient); 320° (middle); and 290° (the youngest). The relative age of the enumerated systems is clearly demonstrated by the nature of their junctions with one another and also by regularities in their mutual distribution on the rocks. Moreover, calcareous incrustations, covered with striation of an older

direction and bearing traces of striation of another, younger, direction [1], were encountered on the coastal nunataks in the region of Mirnyy. Subsequently, similar calcareous incrustations were discovered on other portions of the coast also, throughout the sector of the expedition's work, on which examples of the above-mentioned striations were likewise observed. The Australian geologist Peter Kroon [transliteration] has informed the author of the existence of similar systems of striations (young and middle) in the region of the Australian southern polar observatory, Mawson.

Thus, it ultimately became possible to extend to a portion of the coast of Eastern Antarctica over 2,000 km in length, the regularities established at first only for the region of Mirnyy. Analysis of the material obtained justified advancement of the hypothesis that, in the given region, traces are observed of three phases of glaciation of the continent, separated from one another by epochs of relative warming of climate, during which calcareous incrustations could be deposited on the rocks. Sharp contractions of the glacial shield of Antarctica and migrations of the center of growth of glaciation took place during such interglacial epochs. Judging from a preliminary analysis of the vector diagram of striation, the basic center of growth of the oldest glaciation was apparently located somewhere in the region of the South Geographic Pole, but thereafter in the course of time shifted to the north, somewhere in the direction of the present South Magnetic Pole.

Considering the data of D. Khau [transliteration, Howe?] and also A. P. Lisitsin and A. V. Zhivago, it may be supposed that traces of the Mindel, Riss, and Würm glaciations [2, 3] exist in the area of investigation of the Soviet Antarctic Expedition. This supports the correctness of statements on the synchronism of glaciations of both sub-polar regions of the earth.

As in the northern hemisphere, the Riss glaciation in the Antarctic was evidently the greatest in scale. Data from echo-sounding carried out by the author on the diesel-electric ship "Lena," and especially the observations of A. P. Lisitsin and A. V. Zhivago on the diesel-electric ship "Ob," support earlier hypotheses that the contemporary submarine banks around Antarctica are, to a significant extent, the terminal moraines of maximum glaciation and correspond to the extreme northern position of the edges of the great ice shield of Antarctica in the past. According to the data of A. P. Kapitsa, which he obtained as a result of seismic sounding of Drigal'skiy Island, the thickness of such a morainic cover of the submarine bank of Davis Sea can be measured in many tens of meters.

There is every basis for taking the mean cross-sectional profile of the coastal zone of the contemporary glacial shield of Antarctica as the natural profile of equilibrium of this shield, characteristic for the

entire Quaternary period. Accepting this proposition and transferring the coastal terminus of this profile to the edge of the Davis bank (the terminal moraine), it is possible to establish that, in the epoch of maximum glaciation of the Antarctic, the thickness of the continental ice over the region of Mirnyy observatory equalled 1,000-1,100 meters. This figure is found in accordance with materials of other investigators, obtained as a result of direct observations on hypsometric indications of morainic material on the slopes of coastal mountains (Mt. Gauss, etc.).

Using a similar method of estimation of the thickness of the ancient glacial shield in the coastal zone of Antarctica, we arrive at the possibility of estimating, although crudely, the mass of ice lost by this continent at the end of the epoch of maximum glaciation. By the same means, evaluation of the significance of the eustatic factor in the variation of the level of the world ocean during the Quaternary period may become significantly closer to reality.

B. Marine Terraces. Clearly reflected marine terraces of an altitude of 5-7, 10-15, 25-30, 45, 60, 90 and 120 meters were observed by the author, E. S. Korotkevich, L. D. Dolgushin, Yu. M. Model' and other staff members of the First Soviet Antarctic Expedition in the oases of Grirson, Langeneset [transliterations] and other places on the coast of Eastern Antarctica. On the 40-meter terrace of Grirson Oasis, the mummified corpse of a sea elephant was discovered. Numerous remains of shells of mollusks and foraminifera, tubes of sea worms, etc., and also bones of penguins and seals, were found in Langeneset Oasis, on terraces of an altitude of 5-7 and 10-15 meters. Here also were observed large salt lakes at various stages of desiccation, in the cumulative terraces of which were encountered sheets of mirabilite up to one meter thick. These lakes were located on the sites of former fiords. It is quite obvious that these coastal terraces and salt lakes are irrefutable witnesses to very recent upward movements of the antarctic continent [1].

A similar phenomenon is confirmed as characteristic for the whole of Eastern Antarctica by the data of T. David and P. Priestley for the area of the west coast of Ross Sea, where they also observed clearly-reflected 10 and 30-meter terraces with remains of marine fauna, and in addition sheets of mirabilite on the banks of local lakes [4].

The amplitude of such very recent upward movements is obviously measured in many tens of meters. We recall that members of the expedition of E. Shackleton, in 1907-1909, observed remains of marine fauna and flora on the slopes of the volcano Mt. Erebus at an altitude of about 100 meters, and a member of the First Soviet Antarctic Expedition, E. S. Korotkevich, found at the summit of Mt. Gauss (alt. 370 meters) a pebble, beautifully rounded by water from the basalt composing this extinct volcano. Here also, the author found in the continental ice, at an altitude of about 70 meters above sea-level, remains of contemporary marine algae.

Considering that all regions of blanket Quaternary glaciation (Greenland, Scandinavia, etc.) are experiencing elevation at the present time, the very recent upward movement of Antarctic material [sic, possible typo for МАТЕРИКА "continent"?] should possibly be explained by isostatic equalization, beginning after the loss by Antarctica of a load of hundreds of thousands of cubic kilometers of ice at the end of the epoch of maximum glaciation.

C. Neotectonic Disjunctive Complications of the Shelf. On examination of the configuration of the continental slope of Antarctica in plan, and also the configuration of its ice shield, it is easily possible to note the presence of a whole series of surprisingly straight orographic lines with an extent of many hundreds of kilometers, outlining this part of the continent. Usually reflected in the form of abrupt ledges, they can of course be best of all explained by the presence of a vast zone of coastal faults, along which part of the Eastern Antarctic platform subsided at some time onto the bottom of the Indian and Atlantic Oceans. This working hypothesis, proposed by the author in 1955, was confirmed by him through the results of echo-soundings of the bottom of Davis Sea from the diesel-electric ship "Lena" and the motor ship "Kooperatsiya." (On 10 October 1955 at the time of his report at a session of the division of physical geography of the USSR Geographical Society, the author demonstrated a corresponding tectonic scheme of the Antarctic.)

On the echo-sounding charts of slopes of the Davis bank, and especially of the northern slope of the Davis trough in the region of Mirnyy, traces of very recent displacement of the earth's crust in blocks are clearly evident in sharp ledges in the submarine relief, and also in characteristic narrow depressions with a v-shaped cross-sectional profile. Judging from the appearance of the Davis trough, it also corresponds to a series of large-scale faults in the continental shelf, closely parallel to the local edge of the ice shield.

Several large-scale ledges in the submarine relief, very conspicuous on the meridional profile of Antarctica, deserve special attention. Their depressed upper surfaces, about 20-25 km in width, undergo a steady slope to the north at an angle of about 20', while their northern and southern slopes clearly reveal a disjunctive nature by their abruptness. A seismic profile constructed by A. P. Kapitsa indicates the existence of similar ledges under cover of the continental ice south of Mirnyy.

It is highly probable that the upper surfaces of such ledges are relics of the ancient shelf of Antarctica, which has subsequently undergone changes of its component parts in blocks, in connection with isostatic upward movements of the periphery of the continent, accompanying the southward retreat of the edge of the ice shield.

Independently of the author, A. V. Zhivago and A. P. Lisitsin arrived at conclusions close to his, after analyzing the results of their numerous bathymetric observations on the diesel-electric ship "Ob," along the shelf of Eastern Antarctica between the region of Mirnyy and the meridian of the South Magnetic Pole. These investigators established that the depression within the shelf, represented in the Mirnyy area by the Davis trough, continues further to the east closely parallel to the coast of the continent to d'Urville Sea. A. V. Zhivago and A. P. Lisitsin correctly assume that the given depression defines a massive boundary fault of the continent, formed as the result of a vertical shift of the entire continental mass [2].

Leningrade Mining Institute

Submitted to the Editors
29 March 1958

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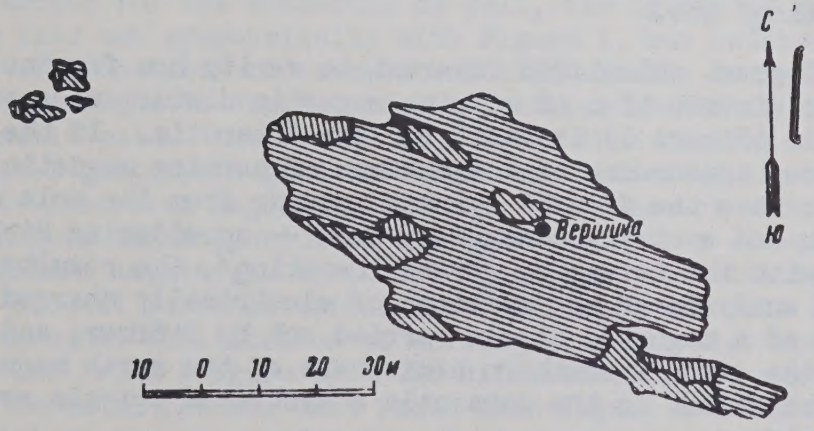
FIGURE



Orientation of glacial striation on "nunatak Vetrov" in the area of the Mirnyy observatory (Composed by P. C. Voronov, 1957)
(In body of figure, one word, "Summit," and letters, indicating "north" at point of arrow and "south" at tail)

DISTRIBUTION OF MAGNETIC DISTURBANCES IN THE ANTARCTIC

Problemy Arktiki, sbornik statey
/Problems of the Arctic, a Collection of Articles/,
No 2, 1957, Leningrad,
Pages 241-244
Russian, per.

A. P. Nikol'skiy

Elucidation of the regularity of geographic distribution of magnetic disturbances is one of the most important tasks in the study of the variable magnetic field of the earth. The programs of the International Geophysical Year, among other problems of terrestrial magnetism, provide for devoting attention to the solution of this task also.

As a result of the study of magnetic disturbances in the Arctic according to the observations of 28 stations including the high latitude aerial expeditions of 1948-1950 and North Pole No 2 drifting station (1950-1951), it was shown /1, 4/, that the isolines of simultaneous appearance of the maximum of morning magnetic disturbances represent a system of spirals issuing from the pole of uniform magnetization of the earth and evolving clockwise. This result was later confirmed /2-3/ by analysis of observations on anomalous absorption and polar auroras. The system of isolines found is represented in Figure 1. This result, together with other conclusions derived in the Arctic Institute regarding the regularity of flow of magnetic disturbances in high latitudes, provides a basis for considering that the ideas of Birkeland-Störmer on the nature of magnetic disturbances are justified to a greater degree than was believed until recently. Apparently, the elements, worked out by them of a theory of magnetic disturbances, reflect reality better and more closely than the later theories of Chapman, Ferraro, Alfven /transliteration/ etc.

It is of great scientific interest to verify how far the regularity of geographic distribution of morning magnetic disturbances established for the Arctic (Figure 1) is valid for the Antarctic. If the isolines of simultaneous appearance of the maximum of morning magnetic disturbances in the Arctic have the form of spirals issuing from the pole of uniform magnetization and evolving clockwise, then — considering Birkeland's experiments with the terrella, /transliteration/, the results of mathematical analysis of the movement of electrically charged particles in the field of a magnetic dipole carried out by Störmer, and the location in the earth's southern hemisphere of the north magnetic pole — they should represent in the Antarctic a system of spirals evolving counterclockwise.

The examination of this question for the Antarctic is especially interesting at the present time; for in the present International Geophysical Year much attention is allotted to study of magnetic

disturbances in the Antarctic. Processing of the observations of the International Geophysical Year will permit a check on the correctness or error of the various hypotheses on the possible regularities of magnetic disturbances in the completely uninvestigated regions of the Antarctic.

Data on the daily progression of magnetic activity and the times of beginning of its maximum are known to us only for three Antarctic stations (Table 1) discussed in the article by Stagg [7].

TABLE 1

CHARACTERISTICS OF THE DAILY PROGRESSION OF MAGNETIC DISTURBANCES

Designation of Station	South Latitude	East Longitude	Geomagnetic Latitude	Local Time of Morning Maximum (hours)	Greenwich Time of Morning Maximum (hours)	Greenwich Time Taken from Isolines (hours)
1	2	3	4	5	6	7
Cape Evans	77.°6	166.°4	78.°9	9	22	20
Cape Denison	67.0	142.7	75.5	12	2-3	3
Gauss Land	66.0	89.6	76.1	10	4	8

For a check on the correctness of conclusions drawn from observations in the Arctic for the Antarctic as well, the system of spirals, Figure 1, was laid out symmetrically with Figure 1, but counterclockwise, in accordance with the laws of movement of electrically charged particles in the field of a magnetic dipole and the location in the Antarctic of the north magnetic pole. The system of spirals thus derived was then superimposed on a geographic grid on which were indicated the above-mentioned three Antarctic magnetic stations. By means of congruence of the pole of uniform magnetization on the laid-out system of spirals with the pole of uniform magnetization in the Antarctic, and rotation of the system in the closest possible coincidence with observed data (column 6), a possible geographic distribution of morning matnetic disturbances in the Antarctic was found (Figure 2). The difference in the moment of the moment of the maximum, between that taken from Figure 2 and that observed, comprises zero hours for Cape Denison, two hours for Cape Evans, and three-four hours for Gauss Land. Thus, the observed data coincide for Cape Evans and Cape Denison with an exactitude of one-two hours with what is derived if the data derived for the Arctic are extended to the Antarctic, and a difference of three-four hours is obtained only for the station at Gauss Land.

In January 1956, the Soviet Antarctic station "Mirnyy," located at 66°38' south latitude, 93°00' east longitude, began to function. Magnetic observations, absolute as well as variational, enter into the program of observations in the work of this station. For variational observations, there is at the station an Eshengagen /transliteration - Eschenhagen?/ magnetograph. Scientific Colleague of the Arctic Institute, P. K. Sen'ko, works as the magnetologist of "Mirnyy" station.

It is a matter of great interest to verify, on the basis of observations at "Mirnyy," how closely the actual distribution of magnetic disturbances corresponds with that suggested in our diagram, which is based on theoretical considerations rather than observations, since data from three stations is inadequate for the whole continent. On inquiry from the Arctic Institute, P. K. Sen'ko announced that, according to data for April, the single clearly reflected maximum of disturbances took place at an interval of five-eight hours world time.

If we turn to Figure 2, we see that the isoline corresponding to eight-hours world time passes through station "Mirnyy." Granted that P. K. Sen'ko's conclusion is based only on the observations of one month, it must be admitted that the result of the observations corresponds well with the scheme of geographic distribution of morning magnetic disturbances which we have suggested.

There is thus reason to consider that the regularities of geographic distribution of morning magnetic disturbances is the same in the Antarctic as in the Arctic, with the sole difference that the spiral isolines in the Arctic evolve clockwise, and in the Antarctic, counterclockwise.

Observations on the great network of stations in the Antarctic during the International Geophysical Year will demonstrate how correct our assumptions are.

Submitted 10 October 1956

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Figure Captions

Figure 1. Isolines of simultaneous appearance of magnetic disturbances in the Arctic (figure on curves are hours of world time).
a -- second zone of polar auroras.
b -- first zone of polar auroras.

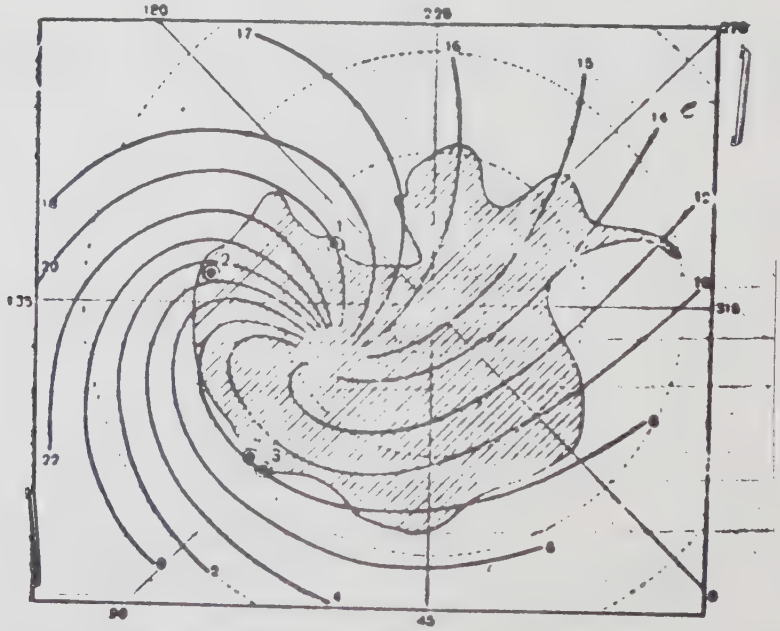

Figure 2. Isolines of simultaneous appearance of magnetic disturbances in the Antarctic (figures on curves are hours of world time).
1 -- Cape Evans; 2 -- Cape Denison; 3 -- Gauss Land;
4 -- Soviet Station "Mirnyy."

THE USE OF DRY ICE FOR DISPERSING CLOUDS IN THE ARCTIC

Problemy Arktiki, sbornik statey
/Problems of the Arctic, a Collection of Articles/,
No 2, 1957, Leningrad,
Pages 133-139.
Russian, per.

A. I. Voskresenskiy,
V. G. Morachevskiy,
V. Ya. Nikandrov

As is known, sailing through ice under conditions of restricted visibility is dangerous, even with contemporary radio navigation aids. The occurrence of a large number of foggy days, when visibility becomes practically zero, is characteristic for the bordering seas of the Soviet Arctic, through which the track of the Northern Sea Route passes. This especially concerns the most unfavorable sectors as regards ice conditions, the straits of B. Vil'kitskiy and Long. As a result, the maneuverability of ships is reduced, and the carrying out of aerial reconnaissance of the ice is made more difficult, as well as the obtaining information on the ice situation by ships.

We shall characterize the fogs in the period of navigation briefly. On the basis of data of many years' observations, it has been established that the greatest frequency of fogs occurs in the first half of the navigation period. The average frequency of fogs in the period of navigation in the various sectors of the track varies from 25-40%, and the number of foggy days in separate months reaches 25.

It must be noted that the data of coastal polar stations on days with fog are low, since fogs are often generated on the edge of ice masses and consequently cannot be observed at polar stations. The distribution of the number of days with fog for the principal sectors of the track can be seen from Table 1 (According to the data of V. Yu. Vize in "Climate of the Seas of the Soviet Arctic," 1940).

TABLE 1

DISTRIBUTION OF THE NUMBER OF DAYS WITH FOG IN THE PERIOD OF NAVIGATION ON THE PRINCIPAL SECTORS OF THE TRACK

Point	V	VI	VII	VIII	IX	X
Dikson Island	6	14	19	15	12	5
Cape Chelyuskin	9	14	23	25	12	6
Great Lyakhov Island	10	13	16	18	12	3
Cape Schmidt	10	13	16	18	12	3
Wrangel Island	10	15	17	16	8	4
Cape Uelen	8	14	16	14	12	4

The duration of fogs in the time of navigation varies from several hours to several days. Thus, at Cape Chelyuskin, several cases have been noted when fog persisted for 60 hours, and on Dikson, 32. Marine fogs, according to observations from ships, are less persistent and comparatively rarely last more than a day.

Their vertical thickness varies from tens to hundreds of meters. Air temperature at the upper limit of fogs in the summer months is, as a rule, negative.

According to data obtained as a result of aerostat launchings carried out by the icebreaker, "F. Likhte," in 1948, the temperature at the upper limit of fogs in the Kara Sea in July amounted to 2-3°, in Laptev Sea in August-September, minus 3-10°.

Successful solution of the problem of action on clouds and fogs for the purpose of dispersing them has an extraordinarily important practical significance for the needs of aviation, the marine fleet, and other branches of the people's economy. Since meteorological processes involve tremendous energy, attempts to overcome them directly are pointless. However, the clearly-expressed contradictory character of development of these processes, leading frequently to unstable conditions, for instance to significant supercooling of moisture of clouds and fogs in liquid-droplet form, opens the possibility of producing essentially qualitative transformations by means of interference in the progress of development of the processes.

The working hypothesis of the method considered here is based on confirmed observations (not only under laboratory, but also under natural, conditions) of examples of the development of meteorological processes in supercooled liquid-droplet clouds and fogs when ice crystals appear in them.

As is known, at the juncture of water with air, and ice with air, the tension of water vapor near the surface of the water and near the surface of the ice is not the same, other conditions being equal. Therefore, with the appearance among the supercooled liquid drops of solid particles (individual ice crystals, snowflakes, frozen drops), the air in the cloud or fog will, to a certain extent, be dehydrated by the attraction of moisture to the ice particles, tending to approximate the saturation near the surface of the ice. In this situation, the drops occurring in the undehydrated atmosphere will begin to evaporate. A so-called distillation of water from liquid drops to ice particles takes place. Along with this, thanks to the constant movement of the drops and ice particles in the cloud, contact between them takes place, leading to their freezing together and, by this very means, to formation of larger particles capable of falling in the form of precipitation.

Hence it follows that introduction of supercooled particles of cooling agents, facilitating the formation of ice nuclei directly from the water vapor present in the air, can serve as one of the effective means of action on clouds and fogs.

At the present time, investigations of methods of acting on clouds and fogs for the purpose of their local dispersal are being conducted very widely, abroad as well as in the USSR. Results having practical significance have been achieved in the development of a method of action for temperatures below zero. In this connection, solid carbon dioxide (CO_2) is employed as the effective reagent. However, the limited range of meteorological conditions under which the method of action of solid CO_2 is effective restricts the possibilities of its use.

Under natural conditions, with normal atmospheric pressure and ordinary temperature, carbon dioxide takes the form of a gas. Carbon dioxide in gaseous form is produced by industrial means, utilizing coke, the waste products of ammonium production, and also the smoke of furnaces of mills and factories. To convert gaseous CO_2 to a solid, it is first subjected to strong pressure in special cylinders with simultaneous cooling, as a result of which it passes into the liquid state. With a surrounding air temperature of + 20°, [liquid] carbon dioxide acquires a pressure of 58 atmospheres. On discharge of liquid CO_2 from the cylinders, a certain proportion (about 20%) solidifies in the form of a snow-like mass, due to loss of heat by evaporation. Under compression, this mass yields blocks of solid carbon dioxide, which, at normal atmospheric pressure, has a temperature of -79.9° degrees. On the application of heat, it does not melt but, by-passing the liquid phase, evaporates, for which reason it is called "dry ice." The heat of evaporation of solid carbon dioxide amounts to about 137 calories per kilogram [?], but a refrigerating capacity of about 152 calories per kilogram [?] is obtained for "dry ice," with use of its cold vapor, in [the course of] warming it to 0°. Since greatest refrigerating capacity of solid carbon dioxide depends on continuous evaporation, the fundamental question of the method of its effective application is the most rational distribution of CO_2 in the supercooled cloud or fog. Three methods of introduction of dry ice from an aircraft into a cloud or fog are customarily employed:

1. Trailing overboard from an aircraft in flight, in special container-evaporators attached to it, of briquettes of "dry ice" which evaporate in the course of movement.

2. Ejection from an aircraft, through diffusors, of outward spreading particles of "dry ice," crushed to sizes appropriate to the thickness of the cloud or fog, and evaporating in the course of descent.

3. Introduction into the cloud of a jet of fine solid particles of CO_2 formed by the discharge of liquid carbon dioxide from cylinders located in the aircraft. Evaporation of such particles takes place in the jet itself, at a distance of several meters from the valve of the cylinder.

The first and third methods can be employed in action on supercooled clouds of moderate thickness (in the order of 100-200 meters). The second method is ordinarily employed when the thickness of the supercooled part of the cloud exceeds 200-300 meters. The advantage of the third method consists in the possibilities of automatic dispersion of the particles of solid CO_2 by discharge of carbon dioxide from the cylinder under pressure, and of its longer keeping.

The physical essence of the processes taking place on introduction of solid CO_2 into the supercooled liquid-droplet cloud or (fog) consists in the following. As is known, formation and disintegration of complexes of molecules of water take place in moist air as a consequence of the forces of molecular interaction. Therefore water vapor in the air is considered as a mixture of several vapors (fractions of complex particles) with a uniform number of combined molecules. To each state of equilibrium dependent on a definite temperature and humidity of the air there corresponds a definite distribution of molecules among the fractions of the vapor. On introduction of solid CO_2 into the supercooled part of a cloud or fog near its upper surface, which has a lower temperature than the temperature of the cloud or fog, the following conditions are created.

a. Changes take place in the process of interchange in equilibrium of individual molecules, and complexes of them; as a result of which, part of the complexes are preserved from immediate disintegration.

b. A tremendous supersaturation of the air with water vapor occurs; thanks to which, these complexes -- despite the fact that they consist in all of a few molecules -- become the nuclei of a new phase of water, which cannot take place in the case of ordinary saturations.

c. In the complexes of molecules held by the air, an arrangement of molecules corresponding to the structure of ice is produced between the surface of the solid CO_2 and the spherical isotherm -40° surrounding it. This is very essential, since if the complexes retained the structure of water, evaporation would occur at the expense of the drops, and the process of crystallization of the supercooled cloud or fog would not take place. Consequently and in general, the influence of dry ice would not be effective.

d. As a result of the abrupt cooling of the air and its supersaturation with water vapor, the complexes of molecules of water acquire the properties of ice nuclei. Thereupon they grow to the critical size at which they are capable, on emerging from the zone of influence of the

solid CO_2, of being enlarged as a result of the difference in tension of the water vapor near the surface of water and near the surface of ice in conditions of normal saturation in a supercooled cloud.

Further development of the process of crystallization in the cloud proceeds on account of the growth of ice nuclei to the dimensions of particles capable of precipitation. At first this growth proceeds in a state of suspension, thanks to diffusion, until attainment by these particles of dimensions of precipitation, usually accompanied by falling.

Such a process of crystallization of supercooled low clouds of moderate thickness, and of fogs, is usually accompanied by their dispersal, as a consequence of the precipitation of enlarged particles and reduction of optical density.

A scientific expedition was organized in the summer of 1956 by the Arctic Institute, for the study of conditions of formation and structure of clouds and fogs. One of its assignments was the conduct of experiments on the active influence of carbon dioxide on supercooled clouds and fogs.

The expedition was equipped with various instruments for study of the structure of clouds (fogs) and had the necessary equipment for production of particles of CO_2. In view of the rapid evaporation of solid carbon dioxide, even in thermostats [Translator's Note: Although this is the only equivalent for the Russian Термостат given in dictionaries available to the translator, it would appear that some such meaning as "refrigerator," "heat-proof container," or the like is intended], its use from aircraft was complicated by the short keeping time. An original airborne installation, designed by us and specially prepared by the experimental workshops of the Main Geophysical Observatory on order of the Arctic Institute, was used in the course of the expedition's work. It consists of a rigid attachment for two cylinders, a manifold, a metering valve, and a diffuser led out through a port in the fuselage. Calibrated openings in the metering valve permit variation of the discharge of solid carbon dioxide per kilometer from 50 to 250 g. Sublimation of the gaseous CO_2 takes place as a result of the abrupt drop in pressure in the diffuser. The installation was designed so that granulation of particles of solid carbon dioxide to a dimension of 0.6 - 0.8 cm in diameter could be achieved with liquid carbon dioxide directly from the cylinders. Particles of carbon dioxide of such a dimension can fly in the open atmosphere to a distance of about 600 meters before complete evaporation. Direct projection of particles of solid carbon dioxide from a "thermostat" was also used.

Flight during which action on a fog was produced took place at a height of 20-40 meters below its upper limit. Also, the particles of CO_2 were spread by a mechanism of turbulent diffusion throughout the volume of the fog subjected to the action. On a rectilinear flight, the breadth of the zone of action amounted to 1.0 to 1.5 km. The priming of this zone with

particles of CO_2 took place within 5-7 minutes of the beginning of the action. The length of the zone depended on the time of the action itself. The apparatus in the possession of the expedition permitted uninterrupted action of up to 30 minutes. To exclude the influence of wind and also to produce an even seeding of the whole volume of the cloud (or fog) with granules of CO_2, a flight on counter-parallel courses by short tacks was used, rather than a straight flight by which only a comparatively narrow corridor cleared of fog (or cloud) is formed. In the course of the expedition's work, a flight pattern proposed by aircraft commander V. I. Vasilyev proved itself well. This pattern consisted of a flight of four counter-parallel courses of a given length and two full banked turns of 7.5 and 15°, so to speak mapping the area of action.

In action on a cloud of a vertical thickness up to 300 meters, the flight altitude at which this pattern was executed was 20-70 meters below the upper edge of the cloud. The area acted upon amounted to 30 km^2 in the course of 11 minutes and remained clear of clouds (or fogs) for 35-40 minutes.

Air temperature and wind velocity at the upper limit of the cloud (or fog) constitute a basic factor determining success of the action. In our experiments, air temperature ranged between -3° and -9° and wind velocity was up to 10 meter/seconds.

As examples we will adduce details of two flights acting on stratus and strato-cumulus clouds.

(1) A flight of 23 September 1956 in the area of the Gydansk peninsula. The meteorological conditions were those of the southern edge of an anticyclone, the nucleus of which was located in the central part of the Arctic basin. An increase in horizontal gradients of pressure was connected with cyclonic activity over Western Siberia. Considerable cloudiness prevailed, and precipitation of a cloudburst type. The wind was in the northwest quarter, moderate. The weather in the region of the action: cloud cover 10/10 Sc, with no openings, lower limit of clouds - 840 meters, upper - 1,350 meters, thickness of cloud 480-500 meters. In the cloud there was strong icing, moderate turbulence, temperature at upper limit of cloud, -12°, glory. Wind velocity was 40 km per hour. Expenditure of CO_2 was 19.5 kg, the zone of action 25-30 km^2. Flight velocity was 280-320 km per hour.

The action took place in the course of 18 minutes at an altitude of 50 meters below the upper limit of cloud

0658 . . . beginning of action

0716 . . . ending of action

0720 . . . beginning of reconstitution of cloud, appearance of column of light (Figure 1)

0722 . . . appearance of gaps in the cloud

0724 . . . land became visible in the fissure

0730 . . . emergence of a clearly defined trench with moderate swelling at the edges, outlining the zone of action

0736 . . . action embraced a solid field with a radius of 20 km

0747 . . . descent for 12 minutes into the zone of action

0759 . . . flight for 9 minutes in the zone of precipitation, altitude 500 meters, snow

0809 . . . blue sky above the aircraft, below, on the ground, precipitation

0824 . . . ascent through the "window" thus formed, area of the cleared region 100-120 km^2

0840 . . . observations terminated, "window" began to close in.

(2) Flight of 22 September 1956 in the region of Talibe-Yaga. The meteorological situation was determined by the western periphery of a ridge of high pressure connected with a sub-polar anticyclone. The weather in the region of action: cloud cover 10/10 St., upper limit of clouds 580 meters, lower 250 meters, thickness 300-350 meters, temperature at the upper limit -9°, visibility in the cloud 120-160 meters, strong icing, turbulence, glory, wind velocity 30 km per hour. Flight velocity was 280 km per hour, expenditure of CO_2 -- 200 grams per km of flight.

0716 . . . beginning of action

0727 . . . end of action

0730 . . . appearance of first gaps

0734 . . . formation of openings to the ground

0737 . . . expansion of the openings (Figure 2)

0755 . . . area of openings, 70-80 km^2

0814 . . . full clearance of the zone of action (300 km^2) from clouds

0850 . . . descent into the gap with optical visibility to the ground

0858 . . . observations terminated because of exhaustion of fuel, zone not closing in

In the period of the expedition's work, 21 actions on supercooled clouds and fogs were carried out. As a result of these experiments, it was established that complete dispersal of stratus and strato-cumulus clouds and fogs with a vertical thickness of up to 500 meters, and a wind velocity of up to 10 meter/seconds, can be achieved by means of action of solid carbon dioxide on them at temperatures of -4° and lower. With a flight pattern lasting 11 minutes and an expenditure of solid carbon dioxide from 50 to 250 grams per kilometer of flight and a total expenditure of 20 kg, the zone of clearance amounts to up to 50 km^2 and lasts up to one hour. Moreover, land begins to show through within 10-15 minutes after completion of the action.

The method of dispersing supercoolec clouds and fogs by use of solid CO_2 can find wide application in the Arctic as a guarantee of take-off and landing at airports, aerial ice reconnaissance (opening of individual areas of the surface of the sea) and safety of navigation through ice, by means of clearing local zones of fog near a moving ship.

Submitted 20 March 1957

Figure Captions

Figure 1. Appearance of a column of light on an area of strato-cumulus cloud subjected to the action of CO_2.

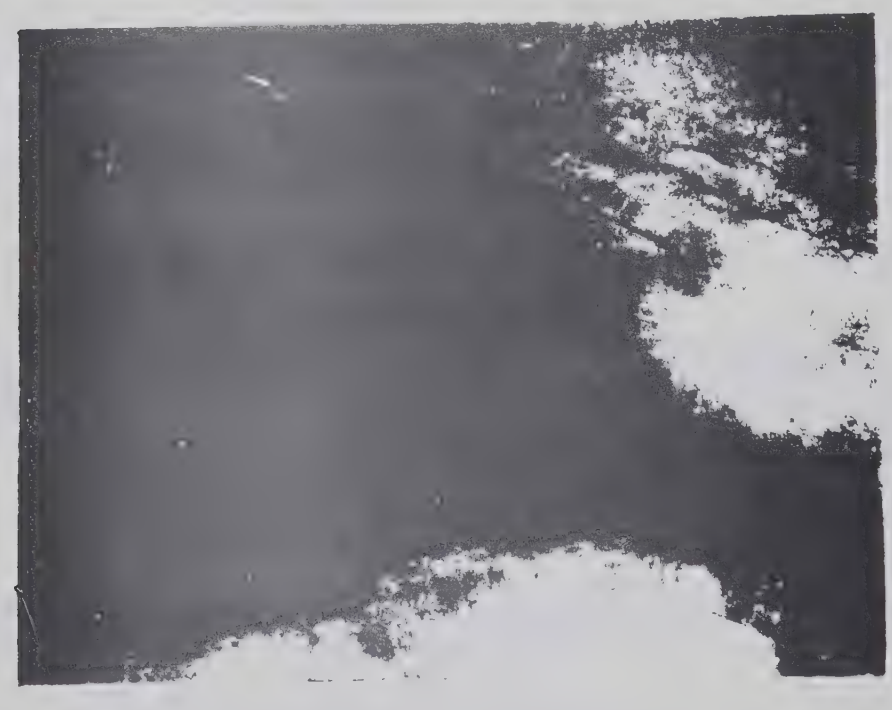

Figure 2. Gaps in a stratus cloud at the end of 10 minutes after ending of the action.

EXPERIENCE OF USING EMPIRICAL FUNCTIONS OF CONTROL FOR FORECASTING TROPOPAUSE LOCATION

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No 2, 1957, Leningrad,
Pages 121-125,
Russian, per.

The existence of a constant correlative connection between the altitude of the tropopause and the values of temperature and pressure in the middle troposphere and the lower stratosphere permits a positive determination of its location on the basis of a given distribution of these quantities. As a consequence of the low accuracy of existing means of computing the latter, however, the effectiveness of prognostic use of the connections mentioned above has usually not been great.

Relatively high dependability of prognosis can be obtained with computation of the altitude of the tropopause by the formula.

$$\Delta H_{тр} = \frac{1}{7.5} (\Delta T_{500} - \Delta T_{200}), \qquad (1)$$

where $\Delta H_{тр}$ = the predicted change in altitude of the tropopause in kilometers.

ΔT_{500} and ΔT_{200} = the expected change of temperature at the levels of the isobaric surfaces of 500 and 200 mb /millibars ?/

The validity of forecasting of the altitude of the tropopause by formula (1) depending on the accuracy of temperature forecasting, is presented in Table 1, computed according to the data of 1,500 radiosonde launchings for the stations Dolgorudnaya and Voyeykovo.

TABLE 1

DEPENDABILITY OF PROGNOSIS OF THE ALTITUDE OF THE TROPOPAUSE
(in percentages)

	Accuracy of Prognosis of $(\Delta T_{500} - \Delta T_{200})$ in Degrees						
	±1	±2	±3	±4	±5	±6	±7
Dependability of prognosis of $\Delta H_{тр}$ to an accuracy of 1 km.	92	89	85	80	72	64	55

The spread in the magnitude of variation between the predicted and factual values of ($\triangle T_{500} - \triangle T_{200}$) is cited in Table 2 as an index of the effectiveness of present means of daily prognosis of temperature.

By comparing the data of Table 1 and Table 2, we find that the dependability of daily forecasting of the altitude of the Tropopause to an accuracy of 1 km according to Formula 1 amounts to about 76%.

TABLE 2

DISTRIBUTION OF ABSOLUTE ERRORS IN DAILY PROGNOSIS OF THE TEMPERATURE DIFFERENCE ($\triangle T_{500} - \triangle T_{200}$)

	Magnitude of Error (in degrees)			
	0 ± 1	2 ± 3	4 ± 5	6 ± 7
Probability of Error (%)	21.3	39.8	18.2	8.3

Thus, the necessity of constructing a chart of the expected temperature distribution not only complicates the practical use of Formula 1, but -- and this is the main point -- introduces great supplementary errors into the calculations. Elimination of the intermediate step of forecasting the temperature range, and a change to determination of the future position of the tropopause directly from the initial charts, together with a simplified method of working out the forecast, can be expected to lead to a certain improvement in its validity.

As an explanation of the possibility of such a change, we will rework to some degree the correlation (1). The local temperature change is determined primarily by processes of horizontal advection and vertical interchange; therefore the equation (1) can be stated with close approximation in the following form:

$$\triangle H_{TP} = \frac{1}{TS}\left[(\triangle T_{500})_{\omega} + (\triangle T_{500})_{\omega} - (\triangle T_{200})_{adv} - (\triangle T_{200})_{\omega}\right] \qquad (2)$$

Using the initial point grid (Figure 1), we will seek a solution of equation (2) for point 0 in the form:

$$\triangle H_{TP} = a_1(t_1 - t_0)(h_1 - h_{II}) + a_2(t_2 - t_0)(h_{II} - h_{III}) + a_3(t_3 - t_0)(h_{III} - h_{IV}) + a_4(t_4 - t_0)(h_{IV} - h_1) + a_5(h_1 + h_{II} + h_{III} + h_{IV} - 4h_0) + a_6(T_1 - T_0)(H_1 - H_{II}) + a_7(T_2 - T_0)(H_{II} - H_{III}) + a_8(T_3 - T_0)(H_{III} - H_{IV}) + a_9(T_4 - T_0)(H_{IV} - H_1) + a_{10}(H_1 + H_{II} + H_{III} + H_{IV} - 4H_0), \qquad (3)$$

where t, h, and T, H = the values of temperature and geopotential, taken according to charts of AT_{500} and AT_{200};

a_i = a certain numerical coefficient.

For brevity of notation, we will introduce the designations.

$$(t_1 - t_0)(h_I - h_{II}) = f_1$$

$$(t_2 - t_0)(h_{II} - h_{III}) = f_2$$

. . . . . .

. . . . . .

$$(H_I + H_{II} + H_{III} + H_{IV} - 4H_0) = f_{10},$$

after which the relationship 3 will take the simpler form.

$$H_p = a_1f_1 + a_2f_2 + a_3f_3 + a_4f_4 + a_5f_5 + a_6f_6 +$$

$$+ a_7f_7 + a_8f_8 + a_9f_9 + a_{10}f_{10} \qquad (4)$$

or, finally,

$$\Delta H_{rp} = \sum_{i=1}^{10} a_i f_i \qquad (5)$$

It is apparent that functions f_1, f_2, f_3, f_4 and f_6, f_7, f_8, f_9 characterize the intensiveness of horizontal advection of temperature at the levels of the isobaric surfaces of 500 and 200 mb -- the first and third components of the right-hand part of Formula 2 -- wile functions f_5 and f_{10} reflect the change in the altitude of the vortex of velocity and should to a certain extent determine the distribution of vertical currents at these altitudes -- the second and fourth components of the right-hand part of expression (2). (A more exact calculation of the vertical currents is possible by means of inclusion in relationship 3 of the horizontal derivatives of the Laplacian geopotential; however, this would require a significant increase in the number of points in the initial grid and a complication of the computations, /which would/ thus /become/ cumbersome and laborious.)

The weighted /?/ coefficients (controlling functions) a_i are computed from factual data. This has a fundamental significance, since the individual terms of relationship 3 determined by such means should reflect, in addition to the processes of horizontal and vertical interchange cited, the influence of factors not subject to exact calculations, such as radiation and absorption of radiation, change in the substantive composition of the tropopause, and the like.

It must be said, however, that coefficients a_i will be constant only in the event that the fundamental prognostic equation properly reflects the physical regularity of the processes leading to change in the altitude of the tropopause.

Choice of the form of the initial grid of points, especially of the distance between them, plays a role of no little importance. The question of choice of optimal value of this distance (differential interval) is extremely complex and is customarily resolved by means of tests depending on the requisite advance timing of the forecast. In our case, the radius of external circumference of the grid may be taken on the basis of the mean velocity of transposition of domes and craters in the tropopause.

A test of the prognostic value of Formula 3 for Dolgorudnaya station was carried out by 12 and 24-hour forecasts. Radiosonde data and charts of the topography of the isobaric surfaces of 500 and 200 mb for 1956 were used as initial materials. Calculations were carried out for each of the basic types of macrocirculation processes, W, C, and E (according to the classification of G. Ya. Vangengeym). /Transliteration/ After checking and culling the material, 30 cases of each type were chosen, according to which the values of a_i were calculated.

Since the method of calculation was common to the different types of circulation, we will consider as an example the means of obtaining the numerical coefficients for cases of westerly circulation with forecast 12 hours in advance. With the aid of a radial grid (Figure 1), values of temperature and geopotential were taken from charts of the topography of the isobaric surfaces 500 and 200 mb at the junctural points of the grid, after which the values of the functions f_i were computed for each of the 30 cases. The magnitude of ΔH_{Tp} was determined according to charts of the tropopause, with radiosonde data taken into account. In this manner a system of 30 conditional equations of formula 4 was obtained, with 10 unknown coefficients $a_1, a_2, a_3 \ldots a_{10}$.

The method of minimum squares was used in solution of the system. We will dwell on this question in somewhat more detail. Let us explain how the coefficients a_i should be related to one another in order that the mean quadratic error of forecast of the altitude of the tropopause by Formula 3 should be minimal. For this purpose, we will compose the function

$$\Phi = \sum_{\gamma=1}^{\gamma=n} (\Delta H^{\phi}_{\text{тр}\gamma} - \Delta H_{\text{тр}\gamma})^2$$

where $\Delta H^{\phi}_{\text{тр}\gamma}$ = factual change in altitude of the tropopause;

$\Delta H_{\text{тр}\gamma}$ = precomputed change in altitude of the tropopause;

γ = sequential number of the conditional equation (case).

To find the minimum of function Φ, which also would obviously correspond to the minimum error of forecast, we equate the derivative

$\frac{\partial \Phi}{\partial a_i}$ to zero.

[illegible]

or, considering formula 5,

[illegible]

whence

[illegible] (6)

The expression (6) can be developed into a system of ten so-called normal equations, solution of which will give the optimum value for the coefficients a_i.

The system of normal equations, resulting after computation of the paired products of the form $f_{1\gamma} f_{2\gamma}$ and their subsequent summation, was solved with the help of machines with an accuracy of computation to five significant figures. The values found for the coefficients a_i are presented in Table 3.

TABLE 3

VALUES OF COEFFICIENTS a_i FOR CASES OF WESTERLY CIRCULATION WITH FORECAST 12 HOURS IN ADVANCE

	Coefficient Number									
	1	2	3	4	5	6	7	8	9	10
$a_i \cdot 10^3$	-63	-56	-167	16	-43	23	34	108	22	103

The values of coefficients for forecast 24 hours in advance and for other forms of macrocirculation processes were similarly determined.

The general validity of forecast of the altitude of the tropopause to an accuracy of one km, evaluated by 20 cases for each series of values of weighted /?/ coefficients amounted on the average to 80-85%, with a coincidence of signs of factual and predicted changes of altitude in 80-90% cases.

In conclusion, it should be noted that, while prognostic formulae can be composed for an entire group of points by the method under consideration, the corresponding computations require the application of high-speed calculating machines.

Received 21 February 1957

Figure Caption

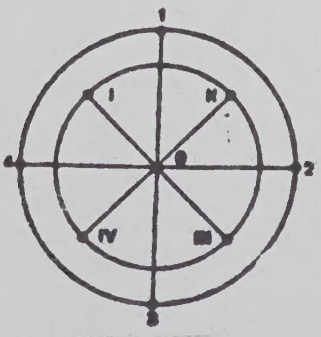

Figure 1. Initial Point Grid

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